Geologic Resource Evaluation Scoping Summary
Petroglyph National Monument, New Mexico

This summary highlights a geologic resource evaluation scoping session that was held at Petroglyph National Monument on March 29, 2006. The NPS Geologic Resources Division (GRD) organized this scoping session in order to view and discuss the monument's geologic resources, address the status of geologic maps and digitizing, and assess resource management issues and needs. Participants at the meeting included GRD staff, staff from Petroglyph and Salinas Pueblo Missions National Monuments, and cooperators from the US Geological Survey, New Mexico Bureau of Geology and Mineral Resources, and Colorado State University (table 1).

Table 1. Scoping Session Participants

Name	Affiliation	Phone	E-Mail
Tim Connors	NPS Geologic Resources Division (geologist)	303-969-2093	tim_connors@nps.gov
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Tobin Roop	Salinas Pueblo Missions National Monument (archaeologist)	505-847-2585, ext. 38	tobin_roop@nps.gov
Ren Thompson	US Geological Survey (geologist)	303-236-0929	rathomps@usgs.gov
Mike Timmons	New Mexico Bureau of Geology and Mineral Resources (geologist)	505-835-5237	mtimmons@gis.nmt.edu
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Gretchen Ward	Petroglyph National Monument (archaeologist)	505-899-0205, ext. 343	gretchen_ward@nps.gov

Wednesday, March 29, involved a welcome and introduction to the Geologic Resource Evaluation (GRE) Program, including the status of reports and map products. During the welcome, Michael Quijano, chief ranger at Petroglyph National Monument, mentioned the direct tie between the cultural and geologic resources and stated, "The geology is why the petroglyphs are here." The morning's discussion focused on map coverage of the monument and other "quadrangles of interest" in the vicinity of the monument. During this discussion, Ren Thompson (USGS) highlighted the geology of Petroglyph National Monument. Afterward, Bruce Heise facilitated a group discussion regarding the geologic processes and features at Petroglyph National Monument. In the afternoon, attendees participated in a short field trip led by Mike Medrano to view petroglyphs and basalt in the Piedras Marcadas Canyon area of the monument.

Overview of Geologic Resource Evaluation Program

Geologic features and processes serve as the foundation of park ecosystems and an understanding of geologic resources yields important information for park decision making. The National Park Service (NPS) Natural Resource Challenge, an action plan to advance the management and protection of park resources, has focused efforts to inventory the natural resources of parks. Ultimately, the inventory and monitoring of natural resources will become integral parts of park planning, operations and maintenance, visitor protection, and interpretation.

The Geologic Resource Evaluation (GRE) Program, which the NPS Geologic Resources Division administers, carries out the geologic component of the inventory. Staff associated with other programs within the Geologic Resources Division (e.g., abandoned mine land, cave, coastal, disturbed lands restoration, minerals management, and paleontology) provide expertise to the GRE effort. The goal of the GRE Program is to provide each of the identified "natural area" parks with a digital geologic map and a geologic resource evaluation report. In addition, the Inventory, Monitoring, and Evaluation Office of the Natural Resource Program Center is preparing a geologic bibliography for each of these parks. Each product is a tool to support the stewardship of park resources and is designed to be user friendly to non-geoscientists.

The scoping process includes a site visit with local experts, evaluation of the adequacy of existing geologic maps, and discussion of park-specific geologic management issues. Scoping will result in a summary (this document), which along with the digital geologic map, will serve as the starting point for the final GRE report. The emphasis of scoping is not to routinely initiate new geologic mapping projects but to aggregate existing information and identify where serious geologic data needs and issues exist in the National Park System. Scoping meetings are usually held for individual parks though some address an entire Vital Signs Monitoring Network.

Bedrock and surficial geologic maps and information provide the foundation for studies of groundwater, geomorphology, soils, and environmental hazards. Geologic maps describe the underlying physical framework of many natural systems and are an integral component of the physical inventories stipulated by the National Park Service in its Natural Resources Inventory and Monitoring Guideline (NPS-75) and the 1997 NPS Strategic Plan. The NPS geologic resource evaluation is a cooperative implementation of a systematic, comprehensive inventory of the geologic resources in National Park System units by the Geologic Resources Division; the Inventory, Monitoring, and Evaluation Office of the Natural Resource Program Center; the US Geological Survey; state geological surveys; and universities.

For additional information regarding the content of this summary, please consult the NPS Geologic Resources Division, located in Denver, Colorado. Up-to-date contact information is available on the GRE Web site at http://www2.nature.nps.gov/geology/inventory/.

The objectives of the geologic resource evaluation scoping meetings are as follows:

- To identify geologic mapping coverage and needs
- To identify distinctive geologic processes and features
- To identify resource management issues
- To identify potential monitoring and research needs

Outcomes of the scoping process include the following items:

- A scoping summary (this document)
- A digital geologic map

- A geologic resource evaluation report

Status of Scoping and Products

As of April 2006, the NPS Geologic Resources Division had completed the scoping process for 160 of 272 "natural resource" parks. Staff and partners of the GRE Program have completed digital maps for 68 parks. These compiled geologic maps are available for downloading from the NR-GIS Metadata and Data Store at http://science.nature.nps.gov/nrdata. The US Geological Survey, various state geological surveys, and investigators at academic institutions are in the process of preparing mapping products for 42 parks. Writers have completed 22 GRE reports with 18 additional reports to be completed by the end of fiscal year 2006.

Geologic Maps for Petroglyph National Monument

During the scoping session on March 29, 2006, Tim Connors (GRD) presented a demonstration of some of the main features of the digital geologic map model used by the GRE Program. This model incorporates the standards of digitization set for the GRE Program. The model reproduces all aspects of a paper map, including notes, legend, and cross sections, with the added benefit of being GIS compatible. GRE staff members digitize maps using ESRI ArcView/ArcGIS format with shape files and other features, including a built-in help file system to identify map units.

Parks in Inventory and Monitoring Network have identified "quadrangles of interest" mapped at one or more of the following scales: 7.5' × 7.5' (1:24,000), 15' × 15' (1:62,500), or 30' × 60' (1:100,000). Often for simplicity, geologic map makers compile maps at scale 1:100,000 (30' × 60'), which provides greater consistency and covers more area. However, for the purpose of geologic resource evaluations, GRE staff would like to obtain digital geologic maps of all identified 7.5-minute (1:24,000-scale) quadrangles of interest for a particular park. The geologic features mapped at this scale are equivalent to the width of a one-lane road.

Map coverage for Petroglyph National Monument consists of four quadrangles of interest (scale 1:24,000): Los Griegos, The Volcanoes (formerly Volcano Ranch), Albuquerque West, and La Mesita Negra Southeast, which are situated on the Albuquerque 30' × 60' sheet (see fig. 1 and table 2).

During the 1990s, the US Geological Survey and New Mexico Bureau of Geology and Mineral Resources cooperatively mapped the entire Albuquerque basin at 1:24,000 scale, which Sean Connell (Mexico Bureau of Geology and Mineral Resources) recently compiled at 1:50,000 scale (GMAP 7469)*:

Connell, S., 2006, Preliminary geologic map of the Albuquerque–Rio Rancho metropolitan area and vicinity, Bernalillo and Sandoval Counties, New Mexico: New Mexico Bureau of Geology and Mineral Resources Open-File Report 496, scale 1:50,000 (GMAP 7469).*

*"GMAP" numbers throughout this summary are identification codes associated with the GRE database.

Maps at scale 1:24,000 are necessary for understanding the volcanic history of the monument, identifying vents and lava tubes, and planning infrastructure (e.g., trails). According to Ren Thompson (US Geological Survey), 1:24,000-scale mapping will not show specific volcanic features; however, it is a good starting point for resource management. Once 1:24,000-scale mapping is completed, a GeoScientist-in-the-Parks (GIP) may be able to assist with preparing derivative products that highlight specific features (Contact: Judy Geniac, NPS Geologic Resources Division, judy_geniac@nps.gov, 303-969-2015). The preliminary geologic map at scale 1:50,000 (GMAP 7469) will be useful for interpretation, for example, putting the monument into a regional context. Park managers would like to have 1:24,000-scale mapping for the area represented on the park brochure/map plus an additional portion of Los Griegos quadrangle to the north, which includes the remaining portion of the volcanic field.

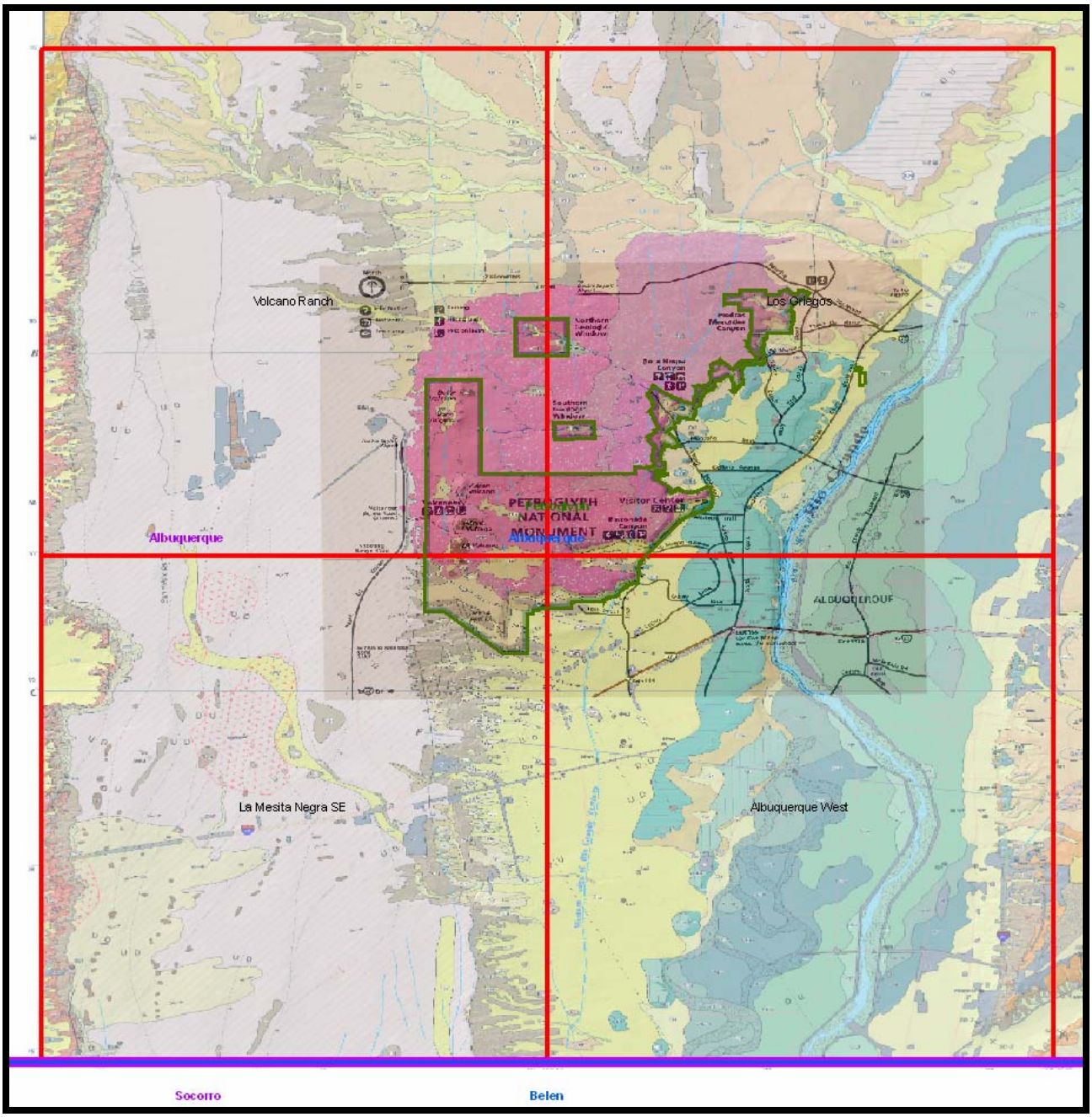

Figure 1. Quadrangles of interest for Petroglyph National Monument, New Mexico. Names in black indicate 7.5-minute quadrangles (scale 1:24,000); names in blue indicate 30-minute by 60-minute quadrangles (scale 1:100,000). Green outline indicates the boundary of the monument. The "shaded rectangle" represents that outline of the park brochure/map.

In order to accomplish the goal of providing 1:24,000-scale mapping of the desired area to park staff, investigators from the US Geological Survey and New Mexico Bureau of Geology and Mineral Resources will cooperate, possibly publishing a dedicated "Geologic Map of Petroglyph National Monument." In the meantime, as data for the northern quadrangles are not currently available, GRE staff would be willing to convert the 1:50,000-scale data (GMAP 7469) of this area into a digital format, which could serve more immediate park use until the 1:24,000-scale mapping project is completed and released.

Data for two of the four quadrangles of interest—Albuquerque West and La Mesita Negra Southeast—are currently available. The US Geological Survey published La Mesita Negra Southeast (scale 1:24,000) in 2003, and the New Mexico Bureau of Geology and Mineral Resources published Albuquerque West in 1998. Hence, the southern portion of the monument's brochure/map is completed.

Ren Thompson mapped The Volcanoes quadrangle, which is currently in review at the US Geological Survey. Reviewers are working out discrepancies in nomenclature of some of the rock units. However, this nomenclature does not affect the area within the monument's boundaries; therefore, Ren suspects that the US Geological Survey may be willing to release these data to the park managers of a sister agency, if they are not made public.

In 1995 the New Mexico Bureau of Geology and Mineral Resources published the surficial geology of a portion of the Los Griegos quadrangle that covers the desired area (GMAP 73587); moreover, basin-fill strata, mapped by Sean Connell, are available. Ren Thompson has mapped the volcanic units of this quadrangle, though completion will require some additional field work. In order to compile a dedicated 7.5-minute geologic map of the portion of the Los Griegos quadrangle of the desired area, the US Geological Survey and New Mexico Bureau of Geology and Mineral Resources will consider entering into a cooperative agreement, the potential outcome being a designated geologic map for Petroglyph National Monument.

Table 2. Quadrangles of Interest for Petroglyph National Monument

Quadrangle	Map citation	Data availability
GRE Plan: Convert USGS or NMBG&MR digital data (scale 1:24,000) into GRE model		
La Mesita Negra Southeast	Shroba, R.R., Thompson, R.A., Schmidt, D.L., Personius, S.F., Maldonado, F., and Brandt, T.R., 2003, Geologic map of the La Mesita Negra SE quadrangle, Bernalillo County, New Mexico: US Geological Survey Miscellaneous Field Studies Map MF-2416, scale 1:24,000 (GMAP 6684).	Digital available from USGS
Albuquerque West	Connell, S.D., Allen, B.D., Hawley, J., and Shroba, R., 1998, Geology of the Albuquerque West 7.5-minute quadrangle: New Mexico Bureau of Mines and Mineral Resources Open-File Geologic Map OF-GM 17, scale 1:24,000 (GMAP 73458).	Digital available from NMBG&MR
GRE plan: Upon completion, convert USGS and NMBG&MR digital data (scale 1:24,000) into GRE model		
The Volcanoes (formerly Volcano Ranch)	Unpublished	Data under USGS review
Los Griegos	Unpublished	Surficial and basin-fill data completed by NMBG&MR, volcanic data completed by USGS (pending field work during FY07)
Interim GRE Plan: Convert NMBG&MR digital data (scale 1:50,000) into GRE model		
Entire Albuquerque basin	Connell, S., 2006, Preliminary geologic map of the Albuquerque–Rio Rancho metropolitan area and vicinity, Bernalillo and Sandoval Counties, New Mexico: New Mexico Bureau of Geology and Mineral Resources Open-File Report 496, scale 1:50,000 (GMAP 7469).	Digital available from NMBG&MR

Geologic Highlights of Petroglyph National Monument

Petroglyph National Monument sits on an intercontinental rift, which has been active for approximately 28 million years. Rifting results in intercontinental basaltic volcanism that produces a variety of sizes of

volcanic fields. Generally speaking, the volcanic field surrounding Petroglyph National Monument is small. For comparison, the volcanic field at Bandelier National Monument is intermediate in size.

American Indians and Spanish settlers carved their images into the desert varnish that covers the basaltic rocks at Petroglyph National Monument. These rocks erupted from “Hawaiian” and “Strombolian” volcanoes. During the Hawaiian phases, great quantities of extremely fluid basaltic lava poured out of fissures on the flanks of a volcano, mainly issuing in lava fountains. Geologists characterize the Strombolian phases (type area: Stromboli, Lapari Islands of Italy) by fountains of fluid, basaltic lava or jetting of clots from a central crater. These volcanoes formed over short time periods from a few fissures (vents). Faults control the location of the vents and sub-basins.

Eruptions resulted in two major packages of basalt: the older basalts (Qbo) represent voluminous activity, while the flows of the younger package (Qby) are smaller volume, vent-related deposits. The Santa Fe basin fill (sediments) separates these two packages, showing two different volcanic events separated in time. Age dating of the older basalt package shows that the eruption occurred over a relatively short period of time. Further dating will help investigators determine the duration of eruptions and the rate of sedimentation of basin fill.

Geologic Resource Evaluation Report

Geologic Resource Evaluation reports include sections about geologic resources of concern for management (referred to as “issues”), geologic features and processes, the park’s geologic history, a map unit properties table that highlights the significant features and resource concerns for each map unit in the park, references (different from the bibliography), and various appendices (e.g., map graphics and scoping summary). This document (scoping summary) will serve as a starting point for information to be included in the final GRE report that will accompany the digital geologic map for Petroglyph National Monument.

Geologic Features, Processes, and Issues at Petroglyph National Monument

The scoping session at Petroglyph National Monument provided the opportunity to capture a list of geologic features and processes operating in the monument, which will be highlighted and expanded in the GRE report. Some of these features and processes may be of management concern.

Cave Features and Processes

Ethnographic studies indicate that the significance of the monument is more than the petroglyphs; in particular, the lava tubes (caves) have great cultural importance. The main issue for park managers at Petroglyph National Monument with respect to caves is protection of cultural resources preserved in the lava tubes. In general, most of the lava tubes are not easy to find; however, as development continues, park staff may need to gate some of these caves because of their cultural significance and for public safety (i.e., many have vertical drops at their entrances).

In 1996 the Albuquerque grotto of the National Speleological Society assisted with an initial inventory of the monument’s caves. This cost approximately $1,000 per cave. Park managers have no plans for any additional cave inventory because the initial inventory provides them with the information they need to manage the caves. In addition, 80% of the monument has been inventoried during an archaeological survey, during which no new caves were discovered; hence, staff is satisfied with their present knowledge base and does not want to draw unnecessary attention to cave resources through a second inventory.

A primary concern about caves is placement of new roads. Park managers need a cartographic study that identifies locales that are potentially hazardous (from collapse) or culturally significant that should be avoided in road development. Ron Kerbo can provide managers with a model cave report that he helped develop for the citing of a new visitor center at Lava Beds National Monument in California. In addition, Ron directed resource management staff to the NPS intranet site at

http://inside.nps.gov/waso/waso.cfm?prg=739&lv=4 (cave and karst page—including NPS cave management policy and guidance sections) and http://inside.nps.gov/waso/custommenu.cfm?lv=4&prg=739&id=2641 (cave management documents) for information and examples about how to prepare a plan.

Stream (Fluvial) Features and Processes
Petroglyph National Monument has a number of ephemeral streams. Park managers would like to obtain baseline data with the potential for comparing current to future arroyo cutting in this rapidly developing area. The county government possesses lidar data that includes the monument. Park managers would like to obtain these data; however, county officials have not been responsive, though they expressed an initial willingness to share this information.

Lake (Lacustrine) Features and Processes
The playas in the vicinity of the monument have concentrated clay soils so are not a source of material for eolian deposits. In the past, playas were sites of human habitation, and cultural artifacts occur on their perimeters. For instance, Judge (1973) developed a sampling strategy that indicated the perimeter of playas as likely locations for the discovery of paleoindian hunting camps. He found several indications at Petroglyph National Monument and throughout the Rio Grande region. Bruce Huckell has been revisiting that work and has done some additional surface survey in the confines of the monument that reaffirm Judge's findings. Huckell has also done some Folsom site excavation work just outside the boundaries of the monument (on state lands) that also confirm the pattern that Judge observed (Gretchen Ward, Petroglyph National Monument, written communication, April 7, 2006).

Judge, W.J., 1973, Paleoindian occupation of the Central Rio Grande Valley in New Mexico: Albuquerque, University of New Mexico Press, 361 p.

In addition to archaeological studies, playas have been the site of paleoclimate studies. Current work by Bruce Huckell (University of New Mexico) has not resulted in any formal publication to date. However, preliminary results from sampling during summer 2004 suggest that the record reaches back to ca. 17,000 BP with nearly one meter of sediment between that date and another of ca. 10,000 BP (Gretchen Ward, Petroglyph National Monument, written communication, April 7, 2006). This means that the Bond-Vulcan Playa may contain a valuable record of past environments spanning the onset of deglaciation and the beginning of the Holocene Epoch. Drs. Huckell and Holliday are conducting this study under a research permit from the monument; they will be doing additional sampling on this particular playa this coming field season.

Windblown (Eolian) Features and Processes
Prevailing winds dump large amounts of sand on the downslope edges of the lava flows in the monument. Eolian processes have implications for cultural sites because wind erosion buries and unburies the petroglyphs. However, the greater concern is adjacent development, which is now a factor in eolian cycles. Development of infrastructure and homes remobilizes existing, previously stable deposits.

Eolian processes influence the ephemeral streams in the monument by filling in arroyos and stream channels, which flooding events later erode. Park managers do not have a thorough understanding of this cycle and need more information.

Hillslope Features and Processes
Though occasional rockfalls occur at Petroglyph National Monument, the substrate is generally stable. Investigators have mapped colluvial deposits related to failure of the escarpment; continued retreat of the escarpment will result in an increasing number rockfall hazards in the long term. In addition, cave

entrances (e.g., Bond Cave) are the sites of rockfall, though cave interiors are relatively stable. Moreover, past quarrying of cinder deposits has resulted in unstable slopes.

Seismic Features and Processes
The primary concern with seismic activity is that an earthquake could affect the escarpment where most of the petroglyphs are. The County Dump Fault has significant displacement with 10,000-year recurrence intervals and magnitude 7.5 potential. In December and January 1997–1998, many Albuquerque residents felt earthquakes originating in the Willard area from a small swarm with individual quakes of up to magnitude 3.8. In January 1971, Albuquerque experienced a 4.4 magnitude earthquake that damaged local buildings. Hence, seismic activity could impact park infrastructure and resources. The US Geological Survey monitors seismic activity in Albuquerque. Seismic activity may be a precursor to volcanic activity.

Volcanic Features and Processes
Petroglyph National Monument hosts one of New Mexico's youngest volcanoes. With the last eruption occurring 150,000 years ago, geologists still consider the system to be active. In the event of a volcanic recurrence, eruption would probably occur along the same "plumbing system" as previous activity.

The volcanic features and the eruptive mechanism they reveal are beautifully laid out at Petroglyph. All the features of the plateau-forming eruptions (e.g., lava lake and lava tubes) are accessible in a very small area. USGS geologist, Ren Thompson, cannot think of any other place where this is true. One noteworthy feature is the type and welding of deposits, which reveal the direction of paleowinds. Fissures controlled the location of vents at Petroglyph National Monument. In general, the volcanic features at the monument are relatively shallow, and thereby fragile. Increased use and development adjacent to the monument could possibly erode some of the features, for example, collapsing splatter cones and destabilizing slopes.

To date, very little erosion has occurred on the volcanic deposits, which creates an opportunity for park planning with the placement of specific trails for interpretive purposes or the avoidance of certain areas for preservation purposes. Because the lava flows contain numerous culturally significant lava tubes (caves), park managers will consider these sensitive areas during planning. Ron Kerbo can assist park managers with preparing a cave management plan that considers culturally sensitive lava tubes (see "Cave Features and Processes" section).

Unique Geologic Features
Petroglyph National Monument is a potential site for testing various dating methods (e.g., argon-39/argon-40 and helium), which is useful for dating young flows. Such age dates are important for understanding how rift-related volcanism works. John Geissman (University of New Mexico, Paleomagnetic and Rock Magnetic Laboratory) presented age dates from the monument during the 2005 fall meeting of the American Geophysical Union. Seventeen furnace incremental heating experiments on 100–200 mg groundmass samples from six sites in the transitionally magnetized basalt of the Albuquerque Volcanoes yield an isochron of 211 ± 22 ka that is within error of previous K-Ar (155 ± 94 ka) and U-Th isochron (156 ± 58 ka) age determinations, but is 3 to 4 times more precise (John Geissman, University of New Mexico, written communication, April 14, 2006). Geissman's sampling sites were arroyos.

Disturbed Lands
During the 1950s and 1960s, mining of cinders at three quarries occurred in what is now Petroglyph National Monument. The cinders were used for making cinder block and railroad-bed material. Through the National Park Service Abandoned Mine Land Program, park staff reclaimed two of the three quarries in 2002. One of the reclaimed sites is on the southeastern corner of Vulcan Volcano and the other is immediately south of the volcano.

Though compliance was also conducted on the third site, it has not been reclaimed. After the original assessment, costs went up and park staff is trying to figure out a way to get the reclamation completed. However, due to its remote location, it is not presently a high priority for park management (Mike Medrano, Petroglyph National Monument, written communication, May 1, 2006).

In addition, disturbed lands include two abandoned motor-cross tracks. Park staff will contact the Geologic Resources Division about future reclamation of these sites.

In the 1940s the US military leased 15,000 acres of desert in the Albuquerque area, some of which is now part of the monument. The volcanic cones were bombing targets. Remnants of this World War II activity remain in the monument; however, the materials were fairly low-energy explosives that were not buried but "bounced" off the basalt. Hence, these materials were not buried and should not be a concern for investigators doing field work.

Geologic Outreach, Interpretation, and Education

In 2003, the New Mexico Bureau of Geology and Mineral Resources published *Albuquerque: A Guide to Its Geology and Culture* in its scenic trip series. This publication contains a geologic tour of Petroglyph National Monument and highlights the potential for future cooperation on educational materials among the National Park Service, New Mexico Bureau of Geology and Mineral Resources, and US Geological Survey.